Proceedings of the 10th International Chemical and
Biological Engineering Conference - CHEMPOR 2008
Braga, Portugal, September 4-6, 2008
E.C. Ferreira and M. Mota (Eds.)

A new strategy for using banana as an ingredient in the brewing process

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Keywords: Beer, Adjunct, Banana, Brewing, Fermentation
Topic: Multi-scale and/or multi-disciplinary approach to process-product innovation

Abstract

Beer is a traditionally fermented beverage made from malted grains of barley, hops, yeast, and water, while banana is an important food crop cultivated widely in tropical and subtropical areas and is one of the major fruits in Brazil. Besides, the banana is also very favorable to food industry (*e.g.* fermented beverages) due to its rich content on soluble solids, presence of minerals, and providing low acidity. In this context, the objective of this work was to evaluate a new strategy for using banana as adjunct to increase the fermentable sugars and to supply a specific aroma in pilot-plant brewing experiments. For this, static fermentations were conducted in a 180 L cylindrical-conical reactor using 140 L as working volume. Addition of banana was evaluated when changing the concentration of the wort from 10 to 12 ºP and from 10 to 13.5 ºP (ºP is the weight of the extract or the sugar equivalent in 100 g solution, at 20 ºC) and fermented under a constant temperature of 10 and 12.5 ºC, respectively. The results showed that the increment in the initial sugar concentration (12 to 13.5 ºP, due to the use of banana juice as adjunct), and in the temperature (10 to 12.5 ºC), increased approximately 17% the ethanol productivity. Thus, it was concluded that by using of simple preparation techniques of banana juice, banana can be used as adjunct in brewing processes, helping in the development of new products as well as in the elaboration of more concentrated worts when compared the traditional brewing worts.

1 Introduction

Produced in large quantities in tropical and subtropical areas, due to the special climatic conditions needed to its growth, banana is one of the most extensively consumed fruits and one of the most significant foodstuffs in the world, while being a good source of mineral salts and vitamins. Sensorial attributes of this fruit, as flavor, taste, texture and color are significantly influenced by its chemical composition, especially by acids, sugars and phenolic compounds. Studies have revealed physicochemical, nutritional and sensorial differences according to the region of origin of the bananas (Cano *et al.*, 1997; Hardisson *et al.*, 2001).

According to Food and Agriculture Organization of the United Nations (FAO, 2008), among the major producers of the banana worldwide in 2006, India was the first with 11.7×10^6 tonnes, which corresponded to 16.5% of the worldwide production, and Brazil was the second with 7.1×10^6 tonnes (approximately 10% of the worldwide production). Thus, banana can be regarded as a important staple food that is critical to the nutritional and economic well being of millions of people throughout the developing world and are grown in about 120 countries (Olorunda, 2000).

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On the other hand, biotechnology includes a wide range of diverse technologies that may be applied in each of the different food and agriculture sectors. In this context, several studies to obtain foods or beverages from fruits, such as orange, grape or apple, have been carried out. In brewing process, the conventional beer fermentation technology is initially based in the wort preparation and on its batch fermentation. With no mechanical stirring and with a temperature profile along appropriate fermentation time, fermentable sugars present in the wort are transformed to ethanol and in several taste and aroma compounds in order to obtain the desired characteristics on the final product (Linko, 1998; Almeida e Silva, 2005).

Nowadays, the brewing industry has applied a whole spectrum of technical, biochemical, microbiological and genetic innovations. Furthermore, in today's competitive beer-market it is very important to develop different types of beers, *e.g.* obtained by the use of new ingredients or new adjuncts. Thus, in previous works we have evaluated the feasibility of new technologies, *e.g*. for selectively producing beers from more concentrated wort (using high maltose syrup), aiming at obtaining good quality beer in a shorter time and in the least expensive way, or using different processing ways (Almeida *et al*., 2001; Almeida e Silva *et al*., 2004; Dragone *et al*., 2004; Brányik *et al*., 2006; Silva *et al*., 2008). By increasing wort concentration, after preparation, the beer is adjusted to the desired ethanol concentration with oxygen-free water, which makes of this process of considerable interest as higher levels of ethanol per given plant capacity and labor costs are obtained.

In this work, the objective was to describe and evaluate the performance of the use of banana juice as adjunct to increase the fermentable sugars and to supply a specific aroma, in pilot-plant brewing experiments. Special attention was paid to fermentation performance in terms of fermentation parameters as volumetric productivity, ethanol yield, and sugars consumption. For this, the addition of banana was evaluated when changing the concentration of the wort from 10 to 12 ºP and from 10 to 13.5 ºP (ºP is the weight of sugar extract equivalent to the weight of sucrose in a 100 g solution/20 ºC), fermented under a constant temperature of 10 and 12.5 ºC, respectively.

2 Materials and methods

The yeast strain used in this work was a commercial lager brewing strain (*Saccharomyces cerevisiae*). The yeast biomass for initial inoculation in the fermentation reactor was cultivated using all malt wort (12.5 ºP) firstly on a rotary shaker (200 mL / 30 ºC / 200 rpm, 18 h), followed by a 4 L Erlenmeyer flask under static and aerobic conditions (2 L / 15 ºC / 0.1 vvm of aeration, 30 h), then in a 40 L stainless steel vessel under static and aerobic conditions (20 L / 15 ºC / 0.01 vvm of aeration, 54-60 h) until the cell concentration was sufficient to provide a cell concentration of 10-20×10^6 cellsmL^{-1} in the beginning of the fermentation in the pilot tank (140 L).

All-malt worts and worts with banana as adjunct were produced according to conventional brewing techniques in the pilot installation used for the experiments, as shown in Figure 1. Banana juice, prepared with fruits of the variety *Prata* (*Musa spp*) and provided by EMATER (Empresa de Assistência Técnica e Extensão Rural do Estado de Minas Gerais, Cristina-MG/Brazil), was used to change the concentration of the all malt wort from 10 to 12 ºP and and from 10 to 13.5 ºP. This banana variety was chosen considering the great production and availability in Brazil which results in accessible price at markets. They were sanitized with running potable water, manually peeled, cut in the form of discs (thickness: 0.5 cm) and triturated in a blender before use. The typical carbohydrate profile of the banana used in this work, classified by the peel color as ripening stage 8 - yellow with more brown specks, according to Loeseck (1950), was: sugars as glucose and fructose (12.4 %ww^{-1}), sugars as sucrose (3.2 %ww^{-1}) and starch (0.5 %ww^{-1}). The banana juice was produced in a concentration of 0.29 gL^{-1} by enzymatic treatment (43.2 ºC during 1.3 h, with agitation at 32 rpm, pH 5 and 8.4x10^{-7} L of Ultra Pectinex SP-L enzymatic pectinolytic solution by gram of medium) followed by a thermal treatment (84 ºC during 0.67 h).

After wort preparation, the initial pH value was adjusted at 5 (by the addition of lactic acid) and the initial dissolved oxygen concentration was set at approximately 8 mgL^{-1}; static fermentations were performed in a 180 L cylindrical-conical tank (brewing fermenter) with 140 L working volume at constant temperature of 10 ºC to wort of 12 ºP and 12.5 ºC to wort of 13.5 ºP. The fermentation runs were carried out until the apparent attenuation was about 70-75% (1.0 ºP above the final value of fermentable sugars).

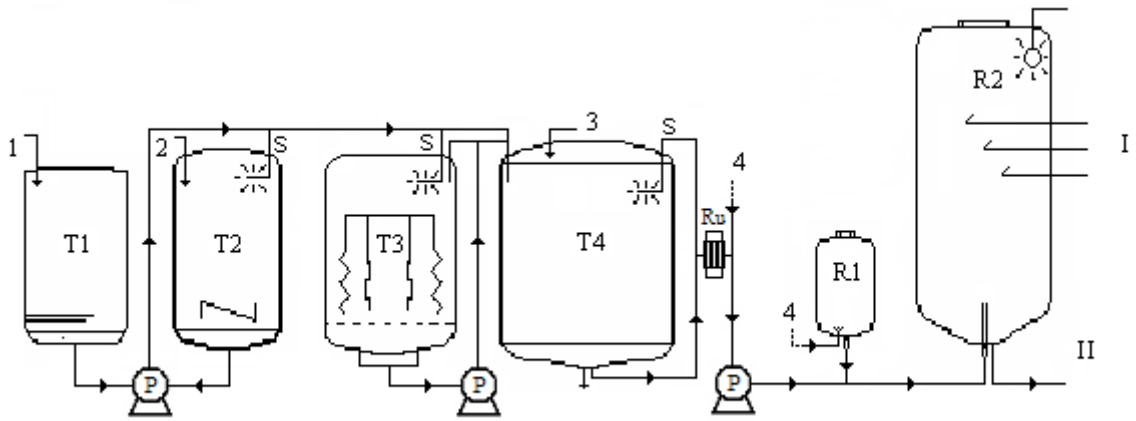

Figure 1. Pilot brewery for wort preparation and beer fermentation (Biotechnology Department at the Engineering School of Lorena, University of São Paulo EEL-USP/Brazil): T1 hot water tank, T2 wort treatment tank, T3 filtration tank, T4 boiling tank, P pumps, S spray-balls (in-line cleaning system), Ru refrigeration unit, R1 inoculation/propagation tank, R2 fermentation/maturation reactor, I and II sampling points or final product, 1 water supply, 2 malt supply, 3 hops supply, 4 air/O_2 supply.

During fermentations, samples were taken in triplicate at specified intervals and the yeast was removed by centrifugation at 4000 g for 20 min. The apparent extract and ethanol concentrations in the supernatant were measured at 20 ºC using an automatic beer analyzer (Beer Analyzer 2, Anton Paar, Graz, Austria). Part of the supernatant was also filtered through a syringe filter (Sep-Pak C18 cartridge, Waters, Milford, MA), and 20 µL were injected into an HPLC system which consisted of an Aminex HPX-87H column (300 × 7.8 mm^2, Bio-Rad Laboratories Ltd, Hercules, CA) at 45 °C using a Shimadzu chromatograph LC-10AD (Shimadzu Co., Tokyo, Japan) with refractive-index detector. The mobile phase was 0.005 $molL^{-1}$ H_2SO_4 at 0.6 $mLmin^{-1}$ flow rate. Sugar concentrations, reported as glucose, fructose, maltose and maltotriose, were determined from calibration curves obtained with pure compounds. The yeast cell number was determined using a Neubauer counting chamber and the viability was determined by methylene blue staining. All analyses were based on the techniques described in ASBC (1996). The ethanol productivity (ratio between ethanol produced and total fermentation time, $gL^{-1}h^{-1}$) and the ethanol yield coefficient (ratio between produced ethanol and consumed extract, gg^{-1}) were determined after conversion of the apparent extract (ºP) to grams of extract per liter of wort (gL^{-1}).

3 Results and discussion

According with the Figures 2 and 3, in both experiments, the final fermentation time was achieved at 120 h. These Figures show the performance of *S. cerevisiae* (yeast in suspension, lager strain), extract consumption and ethanol production as a function of the time of fermentation. As can be observed, during the first 24 and 36 h of fermentation, using banana as adjunct on 12.0 ºP/10.0 ºC and 13.5 ºP/12.5 ºC, respectively, the substrate consumption (measured in terms of apparent extract) was closely related to the increase of yeast biomass in suspension.

However, and after this time, the concentration of yeast in suspension decreased until the final time due to flocculation effect. This profile is in agreement with conventional profiles for brewing processes (Silva *et al*., 2008; Dragone *et al*., 2004). Besides, several factors are known to affect the cell viability in fermentative process, however, in both experiments obtained in this work the cell viability showed few variations (100-95%).

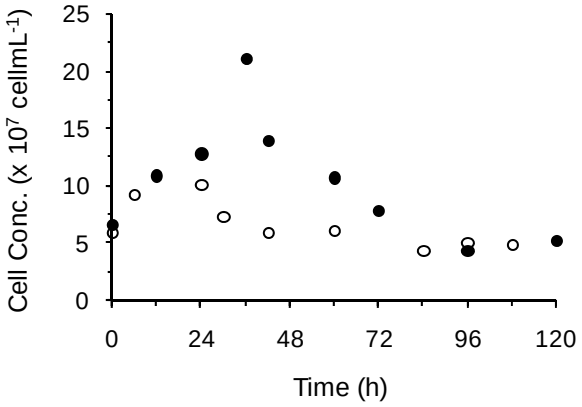

Figure 2. Performance of *S. cerevisiae* (yeast in suspension, lager strain) during fermentation of wort with banana as adjunct under the following conditions of concentration and temperature: (●) 13.5 ºP/12.5 ºC and (○) 12.0 ºP/10.0 ºC.

For the fermentation conditions of this work, the increment in the initial sugar concentration (12 to 13.5 ºP), due to the use of the banana as adjunct, and in the temperature (10 to 12.5 ºC), increased approximately 17% the ethanol productivity. The final productivity of the 12 ºP/10 ºC process was 0.29 $gL^{-1}h^{-1}$, while in the 13.5 ºP/12.5 ºC process was 0.34 $gL^{-1}h^{-1}$. Ethanol yield values were close at the end of each experiment (approximately 0.45 gg^{-1}).

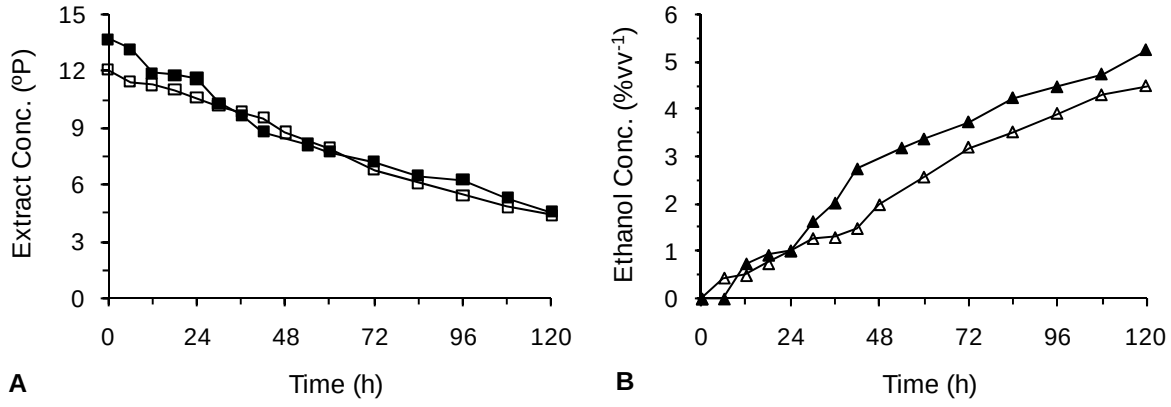

Figure 3. Extract consumption (A) and ethanol production (B) during fermentation of wort with banana as adjunct under the following conditions of concentration and temperature: (■, ▲) 13.5 ºP/12.5 ºC and (□, Δ) 12.0 ºP/10.0 ºC.

Figure 4 shows the profile of the glucose, fructose, maltose and maltotriose concentrations as a function of the time of fermentation. According to Navarro *et al.* (2007), the sugars in wort are not all fermented equally well. Since the yeast has to hydrolyze sugar polymers before it can use them, it always attacks hexoses first. In our work, as shown in Figure 4, comparing the consumption rate for each fermentable sugar found in concentrated wort with banana juice as adjunct, in general the following order of assimilation was observed: part of the glucose was consumed firstly, followed by fructose, maltose and finally maltotriose.

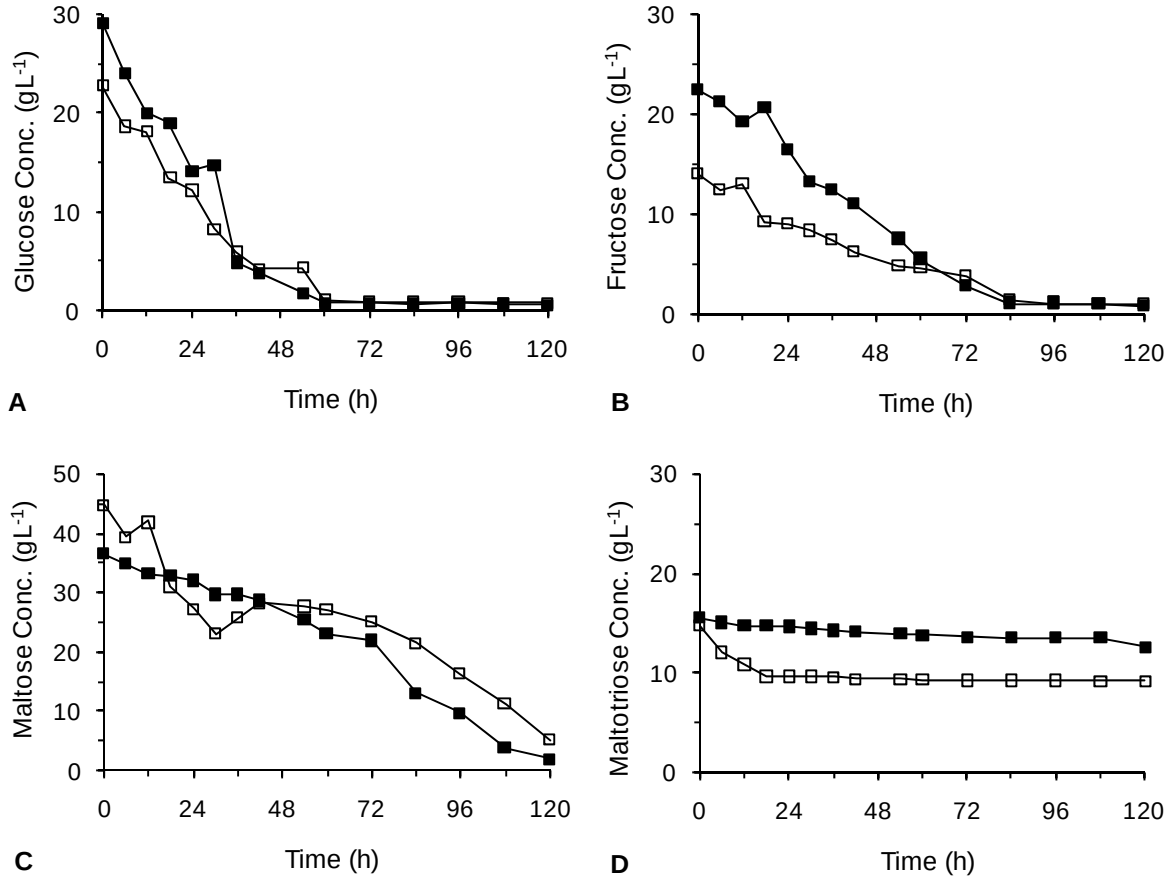

Figure 4. Fermentation performance of glucose (A), fructose (B), maltose (C) and maltotriose (D) at wort with banana as adjunct under the following conditions of concentration and temperature: (■) 13.5 ºP/12.5 ºC and (□) 12.0 ºP/10.0 ºC.

4 Conclusion

From this work it can be concluded that, by using simple preparation techniques of banana juice, banana can be used as adjunct in brewing processes, helping in the development of new products as well as in the elaboration of more concentrated worts when compared the traditional brewing worts (11-12 ºP). As a complement, the authors suggest the use of statistical designs to evaluate the optimization conditions of the variables simultaneously considered in this work (temperature and concentration). Besides, an increased productivity in brewing processes cannot be achieved at the expense of an unbalanced flavor profile of the final product and therefore future works are needed, especially to provide an understanding of the organoleptic profile obtained during the process of beer production using banana juice as adjunct.

Acknowledgements

FAPESP, Malteria do Vale, Corn Products Brasil, Wallerstein Industrial e Comercial, and DiverseyLever (Brazil); FCT (Portugal); and CAPES/GRICES (Brazil/Portugal).

References

Almeida, R.B., Almeida e Silva, J.B., Lima, U.A., Silva, D.P., Assis, A.N. (2001). Evaluation of fermentation parameters during high-gravity beer production. *Brazilian Journal of Chemical Engineering*, 18, 459-465.

Almeida e Silva, J. B. (2005). Cerveja. In: Venturini Filho, W. G. *Tecnologia de Bebidas*. Edgar Blucher, São Paulo, p.347-380.

Almeida e Silva, J. B., Lima, U. A., Silva, D. P., Almeida, R. B., Assis, A. N. (2004). Evaluation of factors involved in the concentration of vicinal diketones in beer produced by high gravit. *Cerevisia*, 29, 147-154.

ASBC, American Society of Brewing Chemists (1996). *Methods of Analysis of American Society of Brewing Chemists*. ASBC. 8ª. ed. Saint Paul Minnesota. USA.

Brányik T., Silva, D.P., Vicente, A.A., Lehnert, R., Almeida e Silva, J.B., Dostálek, P., Teixeira, J.A. (2006). Continuous Immobilized Yeast Reactor System for Complete Beer Fermentation using Spent Grains and Corncobs as Carrier Materials. *Journal of Industrial Microbiology and Biotechnology*, 33, 1010-1018.

Cano, M.P., Ancos, B., Matallana, M.C., Camara, M., Reglero, G., Tabera, J. (1997). Differences among Spanish and Latin-American banana cultivars: morphological, chemical and sensory characteristics. *Food Chemestry*, 59, 411-419.

Dragone, G., Silva, D.P., Almeida e Silva, J.B. (2004). Factors Influencing Ethanol Production Rates at High Gravity Brewing. *Food Science and Technology / Lebensmittel-Wissenschaft + Technologie*, 37, 797-802.

FAO, Food and Agriculture Organization of the United Nations (2008) FAOSTAT statistics database http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567 (last updated 11 May 2008).

Hardisson, A., Rubio, C., Baez, A., Martin, M., Alvarez, R., Diaz, E. (2001). Mineral composition of the banana (*Musa acuminata*) from the island of Tenerife. *Food Chemistry*, 73, 153-161.

Linko, M., Haikara, A., Ritala, A., Penttilä, M. (1998). Recent advances in the malting and brewing industry. *Journal of Biotechnology*, 65, 85-98.

Loeseck, H. W. (1950). *Chemical changes during ripening. Bananas – chemistry, physiology and technology*, Volume 4, Interscience, New York.

Navarro, S., Pérez, G., Navarro, G., Mena, L., Vela, N. (2007). Variability in the fermentation rate and colour of young lager beer as influenced by insecticide and herbicide residues. *Food Chemistry*, 105, 1495-1503.

Olorunda, A.O. (2000). Recent advances in post harvest technologies of banana and plantains in Africa. *Acta Horticulture* 534, 517-527.

Silva, D. P., Brányik, T., Dragone, G., Vicente, A. A., Teixeira, J. A., Almeida e Silva, J. B. (2008). High gravity batch and continuous processes for beer production: evaluation of fermentation performance and beer quality. *Chemical Papers*, 62, 34-41.